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A 2 THz Heterodyne Array Receiver for SOFIA

Summary of Research

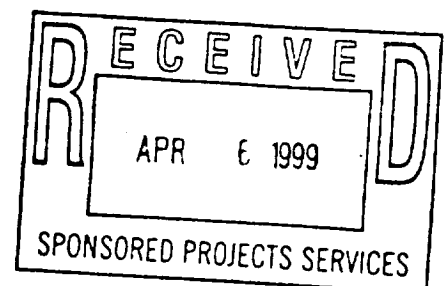
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## Summary of Research

We proposed to perform a comprehensive design study of a 16-element heterodyne array receiver for *SOFIA*. The array was designed to utilize hot-electron bolometers in an efficient, low-cost *waveguide* mount to achieve low noise performance between  $\sim 1500$  and  $2400$  GHz. Due to the prevailing physical conditions in the interstellar medium, this frequency range is one of the richest in the FIR portion of the spectrum. An array designed for this wavelength range will make excellent use of the telescope and the available atmospheric transmission, and will provide a new perspective on stellar, chemical, and galaxy evolution in the present as well as past epochs. A few of the most important molecular and atomic species which the instrument will sample are CII, OI, CO, OH, NII, and CH. The system used the most sensitive detectors available in an efficient optical system. The local oscillator was a compact CO<sub>2</sub> pumped far-infrared laser currently under development for *SOFIA*. The backend spectrometer was an array acousto-optic spectrometer (aAOS). The spectrometer utilizes *proven* hardware and technologies to provide broadband performance ( $\geq 1$  GHz per AOS channel) and high spectral resolution (1 MHz) with the maximum sensitivity and minimum complexity and cost. The proposed instrument would be the fastest and most sensitive heterodyne receiver ever to operate in the 1.5 - 2.4 THz band.

One of the key technologies developed for the proposed instrument is the laser micromachining of waveguide structures. These structures provide both the optical link between the instrument and the telescope (via an array of efficient feedhorns) and the impedance transformation between the detectors and free space. With the assistance of funds provided from this grant, we were able to fabricate and test the world's *first* laser micromachined feedhorns. Figure 1 is a photograph of the 2 THz double feedhorn structure designed and constructed under the auspices of this grant. The quality of the waveguide structure is *far* better than that obtainable using any other fabrication technique. Figure 2 is the beam pattern obtained from it. The beam parameters are an excellent match to what is expected from theory.

The success of this experiment demonstrates the viability of using laser micromachined components in the development of high performance, large format array receivers. Figure 3 is an illustration of the focal plane array concept we developed for *SOFIA* base upon this work. Unfortunately, our instrument proposal was not selected as a first generation *SOFIA* instrument. However, we have continued our development efforts and will propose to build a 2nd generation instrument based on the same design concepts.

Our work under NAG 2-1057 was very rewarding and we appreciate the opportunity provided by NASA to pursue it. The research led directly to publishing 2 papers (listed below) and the award of an NSF grant to our group to construct a laser micromachining system on the University of Arizona campus.

Grant Related Publications: Walker, C. K., and Bloomstein, T. 1998, *Laser Micromachining of Silicon: A New Technique for Fabricating TeraHertz Imaging Arrays*, Astronomical Telescopes and Instrumentation, SPIE Symposium, Kona, Hawaii, in press.

Walker, C. K., and Bloomstein, T. 1997, Laser Micromachining of Silicon: A New Technique for Fabricating High Quality TeraHertz Waveguide Components, *Proceedings of the Eighth International Symposium on Space TeraHertz Technology*, eds. Blundell and Tong, Harvard University.

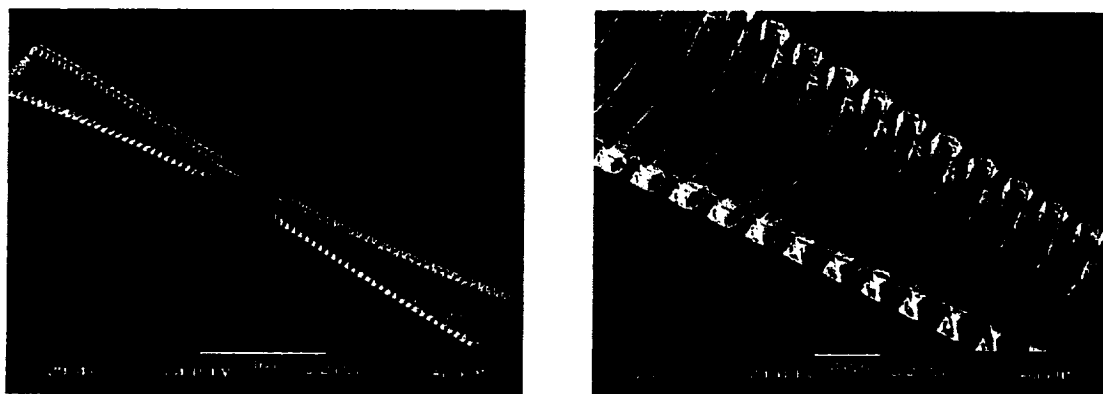


Figure 1: SEM micrograph of replicated version of 2 THz waveguide structure. The original structure was etched using 3 Watts of laser power focused into a  $4\text{ }\mu\text{m}$  spot in 200 Torr of chlorine gas. The laser beam was scanned at 4 cm/s and incrementally moved 2 micrometers between line scans removing  $0.65\text{ }\mu\text{m}$  shavings per pass of the laser over the surface. (b) SEM close-up of ridges.

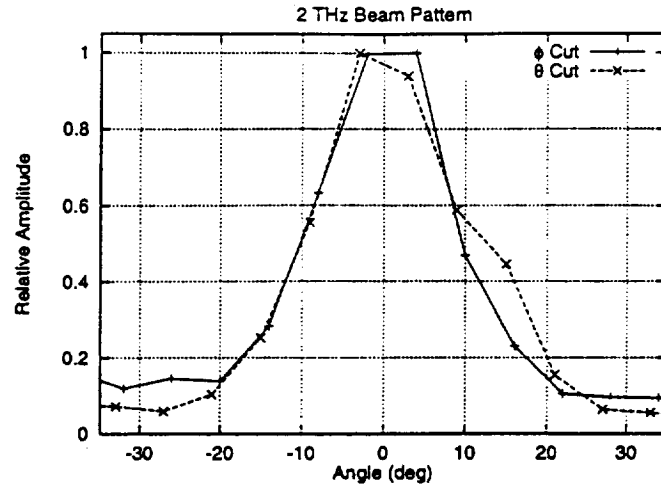


Figure 2: Beam cross scans of the micromachined 2 THz feedhorn. The  $\theta$  and  $\phi$  cuts are orthogonal to each other.

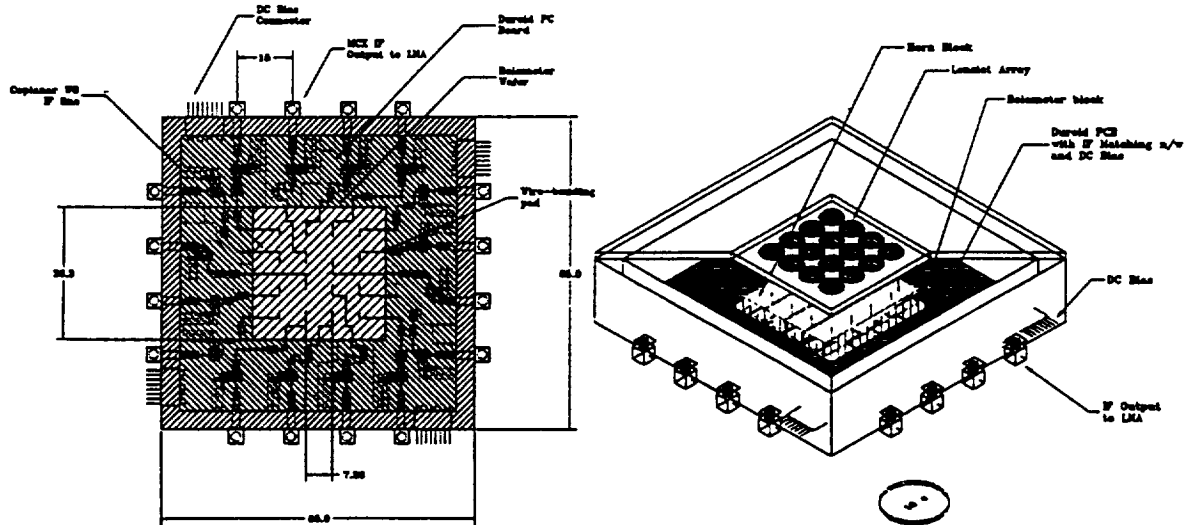


Figure 3: (a) Bolometer (HEB) Array Block showing the Duroid PC Board containing the IF matching network and DC bias lines for the HEBs. (b) Overall 3-D isometric view of the mixer block with lenslet array, feedhorn section, junction and backshort blocks and the IF matching network PC board. The size of a dime is shown for comparison alongside the mixer block. All dimensions are in mm.